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**Columbia River Estuary Habitat Restoration:
Background and Context Regarding the Lois Island
And Miller-Pillar Habitat Restoration Project**

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Introduction

The Biological Opinion ("Opinion") for the Columbia River Channel Improvement Project evaluated the potential effect of the Project on salmonid species listed under the Endangered Species Act. This evaluation included a review of the effects of proposed restoration projects at Lois Island and Miller-Pillar. With regard to these restoration features the Opinion concluded that there could be short term impacts to listed species. With regard to long term benefits the Opinion concluded that:

> The proposed [Lois Island Embayment] restoration feature will be beneficial to ESA-listed salmonids by improving habitat complexity, connectivity, or conveyance, feeding habitat opportunity, refugia and habitat-specific food availability. Biological Opinion on the Columbia River Channel Improvements Project (2002), page 67.
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> This habitat restoration feature [Miller/Pillar] should benefit habitat complexity, connectivity, or conveyance, feeding habitat opportunity, refugia and habitat-specific food availability. Biological Opinion on the Columbia River Channel Improvements Project (2002), page 69.

The Opinion and the Biological Assessment provided by the Corps of Engineers provides a lengthy review of Project impacts. The purpose of this paper is to provide a concise summary of the applicable information in these documents to provide a context for understanding the restoration features and the Opinion's conclusion regarding their long term benefit. This paper reviews background information regarding the Columbia River salmon resource, the function of the river's estuary in salmon productivity, and the role of the estuary in promoting salmon recovery.

Background

The Columbia River and its tributaries comprise the second largest river system in the United States, with a watershed of some 270,000 square miles touching seven states and two Canadian provinces. Home to all five species of Pacific salmon, steelhead, and sea-run cutthroat trout, the Columbia River basin historically produced 10 to 16 million salmon annually, and was the largest producer of chinook salmon in world. (Chapman 1986). Today, less that 2 million salmonids return annually, with an estimated 80% of those originating in hatcheries. Returns declined to a modern low point in 1995 when less than 500,000 salmonids returned to Columbia River basin tributaries and hatcheries above Bonneville Dam.

The century and a half-long decline of salmon in the Columbia River is a function of myriad factors, including widespread habitat destruction, over harvest, hydroelectric development, and an overly optimistic reliance on hatcheries (National Research Council 1996). Today, over half of the salmon populations have been extirpated, and 12 Evolutionarily Significant Units (ESUs) of salmon are now listed under the federal Endangered Species Act as Threatened or Endangered. The listed 'species' or ESUs (equivalent to Distinct Population Segments) in the Columbia River basin include Snake River spring-summer chinook (T), Snake River fall chinook (T), Upper Columbia River spring chinook (E), Upper Willamette River chinook (T), Lower Columbia River chinook (T), Snake River Basin steelhead (T), Upper Columbia River steelhead (E), Middle Columbia steelhead (T), Willamette River steelhead (T), Lower Columbia River steelhead (T), Columbia River chum (T), and Snake River sockeye (E). With the last of these 'species' listed in 1999, the focus has shifted to recovery planning and implementing the regulatory framework that protects listed species, including development of Habitat Conservation Plans and Section 7 consultations on federal actions.

Although returns of salmon to the Columbia River basin have dramatically increased during the past 3 years, sustaining these returns in the years ahead remains a significant challenge because the improvements are largely attributable to improved ocean conditions and concomitant increases in marine survival. Despite the huge amounts of money invested in hatchery reform and improvements in fish passage at dams, the populations are slow to rebound. Clearly, the long-term sustainability of salmon will depend on several factors...not the least of which is an acknowledgment that there is no single action or "silver bullet" for salmon recovery. Moreover, it is even clearer that habitat preservation and restoration will by necessity be a prominent component of any long-term recovery strategy for rebuilding self-sustaining populations. The key to such an approach is to treat the entire salmon life cycle and the supporting habitat in an ecosystem context, and accept the paradigm that habitat diversity supports population diversity that in turn leads to sustainability. The importance of biodiversity cannot be overstated...it is nature's insurance against changing/fluctuating environmental conditions (Levin and Schiewe 2001).

Columbia River Estuary

The Columbia River estuary is unique among west coast estuaries in that it is largely a freshwater system, with seawater intrusion extending only in the deeper channel reaches upstream in the vicinity of Tongue Point and Pillar Rock (*ca.* River Mile 25. At the same time, tidal change can be observed as far upstream as the forebay of Bonneville Dam (River Mile 146). All of the anadromous salmonids of the Columbia River basin are dependent on the estuary either as a migratory corridor or nursery area for extended rearing or both. Those salmonid species and life histories most likely to exhibit the greatest use of the estuary are subyearling ocean-type chinook and chum salmon. As noted above, both species are listed as threatened under the ESA.

Numerous studies have contributed to the current understanding of the estuarine requirements of salmonids. In general, all have identified a suite of critical ecological services provided. These include 1) abundant food supply that supports increased growth rates, 2) refuge from predators, and 3) physiological transition zone for acclimation to salt water (Simenstad et al. 1982). Marsh habitats, tidal creeks and associated dendritic channel networks have been shown to be particularly important habitats for the small subyearling chinook salmon (Levy and Northcote 1982; Myers and Horton 1982; Simenstad et al. 1982). These habitats typically support a high production of insects and other invertebrate prey; serve as sources and sinks for detritus; and because of their complex habitat structure function as potential refuge from predators (Levy and Northcote, 1982).

Several studies have documented the importance of detrital food chains for juvenile salmon (Healey 1982). Estuarine habitats that rate high as sources for detritus include tidal wetlands, low intertidal and subtidal eelgrass, macro-algal beds, and epibenthic algae (Sherwood et al. 1990). Unfortunately, a century of shoreline modification has eliminated some 65% of the Columbia River estuary's marsh and swamp habitat (Thomas, 1983). The organic matter that is literally the foundation of the estuarine ecosystem has largely been cut off from the estuary proper.

The food web of the Columbia River estuary of today contrasts sharply with that of a century ago. Many factors have contributed to the changes, including an altered flow regime associated with hydroelectric production (Bottom et al., In Press; Weitkamp 1994), discharge of industrial and domestic effluents, and a plethora of shoreline modifications including diking, armoring, construction of over water structures, and removal of large woody debris. Taken together, the loss of wetlands and macro-algal habitats (e.g., mud and sand flats) and the enhanced phytoplankton production in impoundments upriver have shifted the estuarine food web from macrodetrital to microdetrital sources (Sherwood et al. 1990). These changes tend to favor the production of pelagic-feeding fishes such as anchovy, smelt, herring, and shad (an exotic species)...and disfavor epibenthic feeders like salmon.

Role of the Estuary in Salmon Recovery

Salmonids in the Columbia River estuary have been the subject of many investigations, beginning with the pioneering research on life history diversity and habitat use by Willis Rich and his students (Rich 1920). Rich's studies were the first to document the complex array of life history strategies displayed by Chinook salmon. Indeed, it was based upon these early studies that led Rich to later propose what was a revolutionary approach to salmon management...that salmon must be managed on the basis of local populations and their supporting habitats (Rich 1939).

Perhaps the most intensive period of research on the Columbia River estuary was the 1979-1980 Columbia River Estuary Data Development Program (CREDDP). The CREDDP investigations were among the first to make the linkage between physical and chemical processes, and the primary and secondary productivity that fuels the estuarine food web (*c.f.* Bottom and Jones 1990; Jones et al. 1990; Sherwood and Creaer 1990; Simenstad et al 1990a, 1990b; Small et al. 1990). As currently defined, these were among the first legitimate examples of an "ecosystems approach" in estuarine ecology.

More recently, the National Marine Fisheries Service, in collaboration with the Oregon Graduate Institute, Oregon Department of Fish and Wildlife and the University of Washington, launched a major research effort to understand the role of the Columbia River Estuary in salmon recovery. The initial report, "Salmon at River's End (SARE)" (Bottom et al. In Press), included a comprehensive synthesis of information on salmonid use of estuarine habitat and made extensive use of hydrodynamic modeling to compare and contrast habitat opportunity before development (*ca.* 1880) and under current conditions. Further, the report made a compelling case for an ecosystem-based approach to habitat restoration, emphasizing the importance of population diversity in long-term sustainability and the linkages to the quantity, distribution, and connectivity of complex, diverse habitats.

At about the same time (but in studies unrelated to SARE) NMFS' scientists used a matrix-modeling framework to investigate age and stage-specific mortality patterns in Columbia River salmonids. Noteworthy among the results of this analytical exercise was the demonstration that a modest reduction in mortality of downstream migrant spring/summer chinook salmon during the estuarine and early ocean transition translated into markedly improved productivity (Kareiva et al. 2000)...once again pointing to the importance of the estuarine phase of the salmon life cycle and the important role that the estuary can play in recovery.

Estuarine Habitat Restoration

Efforts to protect and restore habitats in the Columbia River estuary span many decades; however, the intensity of efforts increased dramatically in the 1990s. Many factors conspired to drive this change, but none were more significant than the ESA listings. To halt and reverse the decline required change...and one such change was in the way we think about the estuary.

At about the same time (1995) the Columbia River estuary was officially designed an "estuary of significance" under the Environmental Protection Agency's National Estuary Program. This designation catalyzed a series of events and actions, including the development of a Comprehensive Conservation and Management Plan ("CCMP"). The Plan calls for an inventory of habitat types and a prioritization of those types and their attributes that require protection and conservation. More specifically, however, the Plan calls for the restoration of 3,000 acres of tidal wetlands along the lower 46 miles of the river by the year 2020. The Plan identifies tidal wetlands as "one of the most critical habitats of the estuary, providing nursery and feeding grounds for numerous species..." Furthermore, the Plan concludes that, "restoring tidal wetlands is a key to the health of the ecosystem of the lower river."

The ESA consultation process has been another major catalyst of estuarine restoration. Over the course of several consultations (beginning in 1993), the Biological Opinions for the Federal Columbia River Power System have focused increasing attention on the importance of the estuary to salmon recovery. Most recently, the 2000 Biological Opinion requires the Action Agencies to "protect and enhance 10,000 acres of tidal wetlands and other key habitats" below River Mile 46 (RPA 160).

The Biological Assessment/Biological Opinion for the Columbia River Channel Improvement Project also included an assessment of potential habitat restoration opportunities. Using a set of criteria that included habitat type, function and value to the species; location and ease of implementation; and land acquisition requirements, several key projects were for selected for action. Two projects involved recreating subtidal and inter-tidal habitat: One in the area of Lois and Mott Islands and one in the area of Miller Sands and Pillar Rock. As discussed below, in response to comments and after discussions with the resource agencies, these projects have been modified to focus entirely on creating tidal marsh and intertidal flat habitat.

Lois Island Embayment and Miller Pillar Habitat Restoration

Placed in this context, the Lois Island Embayment and Miller Pillar Habitat Restoration features are potentially important opportunities to create new wetland-marsh habitat in the estuary. As discussed above, tidal marsh-intertidal flats are one of the most endangered habitats in the Columbia River estuary, and a major source of the detritus that fuels the salmon food web. The widespread diking over the last century has served to destroy or disconnect this important source of organic material from the estuary proper.

Given the CCMP management goal of creating/reconnecting 3,000 acres of wetlands by the year 2020 and the FCRPS Biological Opinion RPA requirement for 10,000 acres of estuarine restoration, and the sobering reality that it would require breaching about ½ the existing dikes in the estuary to reach this goal, every opportunity is an important one. It is only through aggressive pursuit of opportunities such as the Lois Island and Millar Pillar projects that such a lofty goal can be met.

The commitment by the U.S. Army Corps of Engineers and the project sponsors to fund a post-construction monitoring program at the restoration sites and at an adjacent control site is an important aspect of this project. The science of habitat restoration is still an evolving technology (Miller and Simenstad 1997). Every habitat restoration project represents both a potential increase in available habitat and an opportunity for increasing the collective knowledge base. Given the complexities of ecosystems, taking full advantage of these opportunities to improve the scientific understanding of ecological linkages among species and their habitats is one of the best ways to build a knowledge base for future restoration activities.

Conclusions

The Columbia River estuary is an important component of the salmonid ecosystem that has been significantly changed by over a century of habitat modification. The cumulative loss of over 65% of the tidal marsh habitat has played a significant role in the alteration of the estuarine food web that supports salmon production. The macrodetrital-based food web favoring salmon has largely been converted to a microdetrital-based web that favors pelagic bait fish species.

The proposed Lois Island Embayment and Millar-Pillar habitat restoration projects are important opportunities to create/restore critical tidal marsh-intertidal flat habitat. A well designed monitoring program, such as required by the Biological Opinion, should serve to document the effects of these projects, and at the same time significantly increase the understanding of the science of estuarine habitat restoration. Although small compared to what has been lost, the Lois Island and Millar-Pillar habitat restoration projects are important opportunities to take positive action toward revitalizing the Columbia's critical estuarine habitat.

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